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Human Body Resistance and Temperature Measurement Device

Wara, S.T. [a], Oghogho, I., [b] Abayomi-Alli, A. [c], Odikayor, C.D.[d] and Essien, M. S.[e]

Product Development / Energy Centre, Department of Electrical and Computer Engineering, General Abdulsalami A. Abubakar College of Engineering, Igbinedion University Okada, Edo State, Nigeria

[a] docwarati@yahoo.com, [b]oghoghoik@yahoo.com, [c]abayomialli_adebayo@yahoo.com [d] dickinsodika@yahoo.com

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Abstract. This paper discusses the design and construction of a human body resistance and temperature measurement device. The device measures the human body temperature and resistance when the sensing probes are placed in contact with the human skin. The design analysis was based on simple electronic circuit theories leading to specification and choice of components used for the construction of the system. After the construction and testing with various individuals the human body resistance and temperature was found to be within the ranges of 1KΩ to 210KΩ and 36.1^{0}C to 37.5^{0}C respectively. The paper discuses the various effect of current on the human body and their implication. The system can be adapted to various fields such as bio-technology, security (lie detector), safety equipment in industries and companies to determine insulation.

Introduction

Due to advancement in technology, human reliance on electricity is on the increase but shock hazards are the major drawback on its use. Safety devices and equipment that help to prevent or reduce shock possibilities are of increasing importance. Under stress or when exposed to conditions involving tension, the human body shows visible changes in its physiological responses such as heart beat rate, blood pressure, temperature, skin resistance to mention a few. With appropriate sensors and transducers these physical quantities can be converted into electrical or intermediate electrical quantities that can be measured by appropriate electronic equipment. The measurement of resistance in engineering practice is important to determine how much current a particular body can withstand on the application of a known voltage [1]. This knowledge helps an individual operating a particular machine or electronic device to select the right amount of insulation necessary to prevent shock hazards. Today measurement of body resistance is used to identify patients at risk of hypovolemia (reduced total body fluid) [2]. The measurement of human body temperature finds suitable application in the medical field and also it helps an individual determine whether or not his body temperature is within the acceptable temperature range. A temperature measurement device [3] which enables women to determine their ovulation by monitoring their body temperature is presently in use. Treatment of heart attack patients by subjecting them to a state of induced hypothermia which requires temperature measurement and monitoring is also being used today by health workers. [4]

Methodology

In order to achieve the aim set out, ongoing research on body temperature [3,4] and resistance [2,5] were studied and various design options and their cost implications were considered. The body resistance and temperature measurement device can be categorized into three major units. These are: the power supply unit, the detector and linearization unit and the output display unit.

Design of the Power Supply Unit

The chosen step down transformer has the following ratings: Voltage rating (240V/12V), Current rating (500mA). The chosen diode is D3SBA10, Peak reverse voltage: 800V, Forward voltage drop: 0.7V. A capacitor value of 4700µF, 25V was used [6]. Two 9V, 0.5A batteries are used as an alternative to provide the 12Volt supply needed in the absence of A.C power supply.

Design of the Detector Circuit

The input resistors R_1 and R_2 = 1M ohms making them as close as possible to the expected human body resistance. C_1 is chosen to be 100nF to enable the removal of the induced mains hum found on the human body. Resistor R_3 is chosen to be 10KΩ to enable the high output of the emitter follower transistor TR_1 to be safely reduced. The chosen transistors TR_1, TR_2 and TR_3 are C9014. The collector-emitter voltage rating is 50V; the max collector power dissipation is 625mW. The maximum collector current is 150mA. [7]. R_4=470Ω, R_5 =47KΩ, VR_1 = 478KΩ. The circuit diagram is shown in Fig 1.

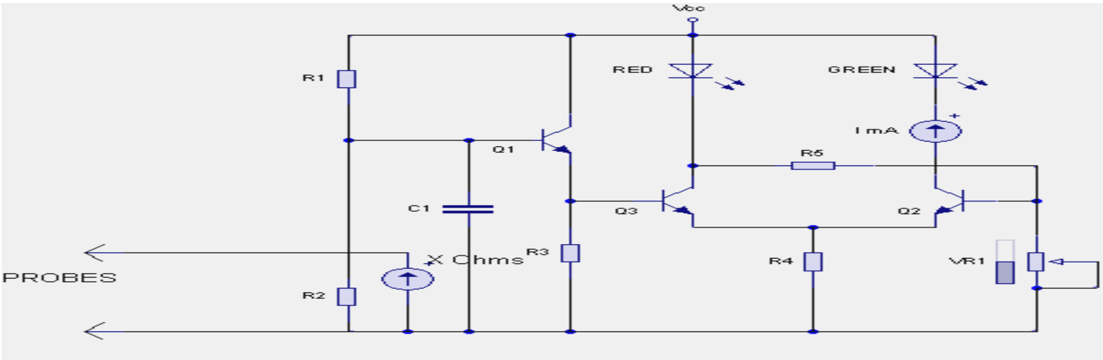

Fig.1 Resistance and moisture detection circuit

Design of the Linearization Circuit

The sensing circuit is excited by the reference voltage, $V_{i/p}$ and is given by the expression

$$V_{i/p} = R_2 / (R_1 + R_2)\, kV_{cc} \quad (1)$$

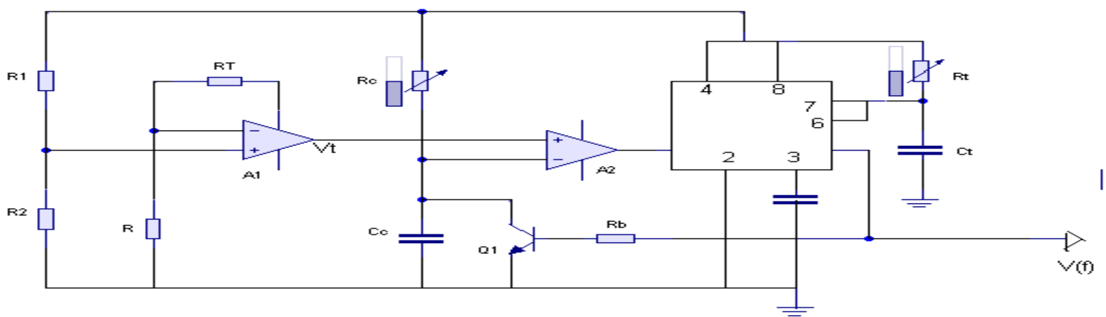

Fig.2. Linearization circuit

K = $R_2 / (R_1 + R_2)$ [8]. From Fig.2, we have that

$$V_t = [\{R + R_t\}\ R]\ V_{ip} = \{1 + R_t / R\}\ kV_{cc} \quad (2)$$

V_t is then fed to the comparator, A2. V_t controls the frequency of oscillation.

The chosen Op-amp is LM741, Maximum input voltage 18V, power dissipation 500mW. Using V_{cc} =7V and Let $V_{i/p}$ =0.6 {approx 10% of V_{cc}}, R_1 is chosen to be = 1.2K ohms

Then from Eq.1, $R_2 = [V_{i/p}/ R_1]/ [V_{cc} - V_{i/p}]$ = [0.6 X 1200]/[7-0.6] =112.5 ohms

R_2 is therefore chosen to be 120 ohms. Thus K=120/1320=0.09, K=0.09.

General purpose **N.T.C** disc thermistor is used. Resistance tolerance = ± 10% at 25^0C, Maximum ambient temperature =1250C, R_0 at 25^0C= 10KΩ. [7] Temperature range= -30^0C to 125^0C

$t_c / (R_cC_c) = \ln (R/[R \{1−K\} −KR_t])$ and $R/[R \{1−K\} −KR_t] =e^{tc/ (RcCc)}$ [9]

$$R= KR_t\, e^{tc/ (RcCc))/ [}\{1−K\}\, e^{tc/ (RcCc)} −1] \qquad (3)$$

$$R = 0.09 \text{ X } 18K/ [\{1−0.09\}− e^{-0.2m/ (100K \text{ X } 21.21)}] = 18.848K \text{ ohms}$$

Design of the Comparator and Monostable Unit

Fig 3. shows the Comparator and monostable unit

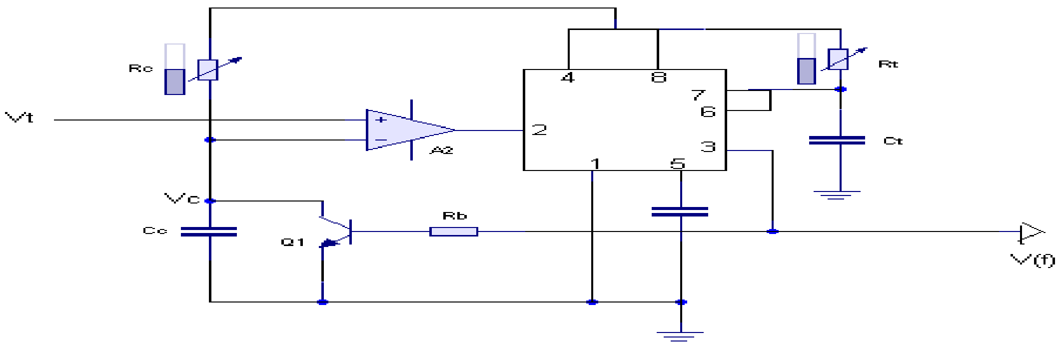

Fig.3: Comparator and monostable unit.

When $V_c = V_t$, the comparator A_2 triggers the monostable circuit. The output pulse of the mono stable circuit with duration, t_w, switches ON transistor Q_1 thereby discharging the capacitor, C_c. After t_w, C_c is charged up again towards V_{cc} until it reaches V_t. This process is repeated continuously and a series of rectangular pulse, whose frequency depends on temperature, is produced at its output. [8]

$$V_c = V_{cc}\ \{1− e\text{-}(t/ \tau)\} \qquad (4)$$

Where $\tau = R_cC_c$.The charging time t_c is obtained when $V_t = V_c$. Thus by equating Eq. 2 and Eq. 4 together we have K $\{1= [R_t/R]\} = 1− e^{-(t/r)}$

$$\text{Where } t_c = R_cC_c \ln (R/[R\ \{1− K\} − KR_t \qquad (5)$$

For a linear relationship to exist between frequency and temperature, then $KR_t = 0$ and

$$tc = R_cC_c \ln R / [R\ \{1− K\}] = R_cC_c \ln \{1/ [1− K]\} \qquad (6)$$

Also $t_c = t_w$ but t_w is set by the monostable timing parameter, giving by

$$t_w = 1.1\ R_tC_t \qquad (8)$$

The chosen monostable is NE555, the supply voltage is 18V, the minimum current is 20mA, Operating temperature 0 − 700C. [7] The pulse width for the comparator, t_c must be equal to the pulse width of the monostable, t_w such that $t_w = t_c$. Let the pulse width $t_w = t_c$= 0.2msec in order to have a fast response and the chosen value of R_c be = 100KΩ. Then from Eq. 6
$Cc = t_c/ [Ra \ln \{1/1− K\}] = 0.2ms/ [105\ln \{1/1−0.09)\}] = [2/\ln \{1/0.09\}]\mu F$
Cc =21.21µF, the chosen capacitor is 470nF, 50V. For the monostable, by chosen Ct = 0.01µF and $t_c = t_w$ =0.2ms for fast response, then from Eq.8 we have that
$R_t = t_w/ 1.1Ct = 0.02ms / [1.1 \text{ X } 0.01 \text{ X } 10\text{-}6] = 18K\Omega$, therefore, R_t is chosen to be = 18 KΩ

The chosen transistor is BC108, the collector-emitter voltage drop is 0.65V, the power rating is 300mW, and the current gain is 110. V (f) will vary between 0V and Vcc ($0 \leq V(f) \leq V_{cc}$). The maximum current, the 555 timer can deliver is 20mA, Thus, if V (f) = V_{cc} =7V, $I_B = I_c$ of the timer (20mA) and $\beta = 80$. [7]

$$\text{Thus } R_B = ([V(f) - V_{BE}] / I_c)\,\beta \qquad (9)$$

$R_{B1} = [\{V(f) - V_{BE}] / I_c)\,\beta = [V(f) - V_{BE}] / I_B = [7 - 0.6] / 20mA = 320\Omega$
If we use minimum current from monostable is 10mA. Then $R_{B2} = [7 - 0.6] / 10mA = 640\Omega$. The chosen value of R_B should be between $320 < R_B \leq 640\ \Omega$. R_B is chosen as 410Ω. The complete circuit diagram of the human body resistance and temperature measurement device is shown in Fig. 4.

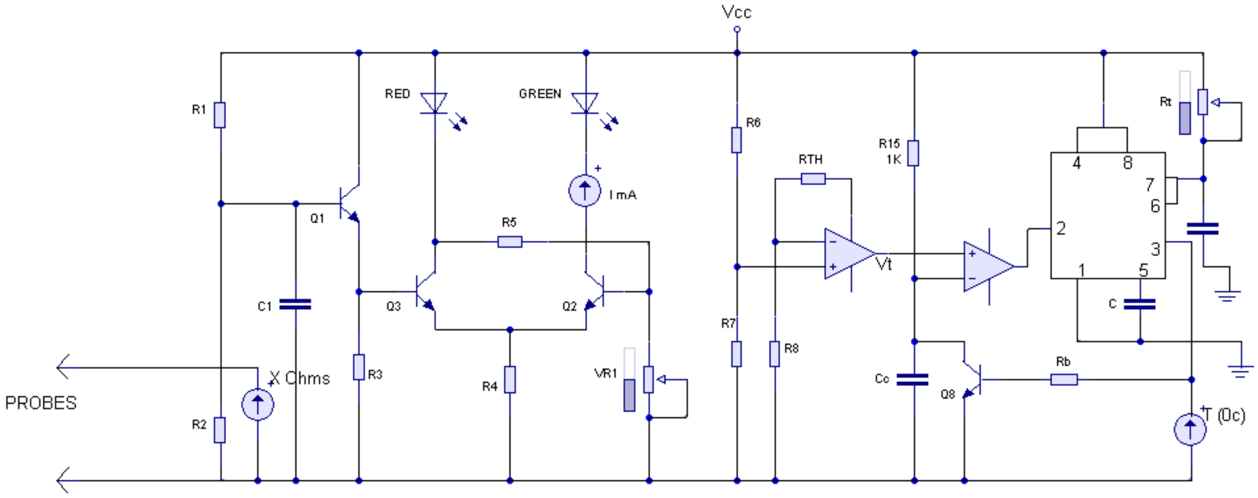

Fig.4: Complete circuit diagram of the human body resistance and temperature measurement device

Principle of Operation

In the detector circuit, when the probes are in contact with the human body, a meter connected across measures the body resistance. Under normal body resistance value, the green LED comes on because the base current of its biasing transistor is higher than the base current of the red LED's biasing transistor, thus the red LED stays off. However when there is a change in the body resistance signaled by the presence of humidity or moisture on the skin which reduces the skin resistance, the comparator circuit consisting of the green and red LED biasing transistors switches and the red LED comes on while the green LED turns off. The third transistor is basically an emitter follower providing large outputs for various values of inputs. The resistors help in either voltage dividing or in biasing of the transistors. The capacitor C_1 is a hum suppressor reducing the induced 50Hz supply frequency from human body. In the linearization circuit, the thermistor acts as the temperature sensor. It responds slowly and non-linearly to temperature changes, hence the need for a linearization circuit to linearize its output. The thermistor is part of a voltage divider circuit of the first comparator whose output triggers the multivibrator that sends out rectangular pulses set by the pulse width which is read by the temperature meter.

Tests

The voltage divider resistors and potentiometer were used to set input into the comparator circuit formed by two transistors thereby setting the green LED to ON when the circuit is powered. First, the sensing probes are then placed on the dry human skin and the result of the indicators is noted. Then the sensing probes are placed on a humid skin and the result noted. Second, a soldering iron is heated up and the sensing probe is placed near to the soldering iron. The result of the indicators is also noted. Third, the sensing probes are placed on moist substance and the result noted. The output display meters and the green and red LED's were closely monitored as the tests were being carried out. When the circuit is powered on, the temperature meter deflects. This is environmental temperature.

Results and Discussion

The table below shows the results of placing the probes on different individuals. When the system is turned on the green LED remains on and the resistance meter reads full scale deflection of about 1M Ω, the current meter reads null and the temperature meter shows the atmospheric temperature. When the sensing probe is placed on a dry skin the green LED remains on and the resistance meter reads the body resistance in ohms, the current meter reads null and the temperature meter shows the body temperature. When the sensing probe is then placed on a humid skin, the resistance meter deflects towards zero depending on the level of humidity or moisture, showing the reduction of the body resistance. The temperature meter deflects depending on the temperature it senses and the current meter deflects indicating that current is flowing through the circuit. The value of 1MΩ standard resistor produces full scale deflection and keeps the green LED on. The values of lower standard resistors produce reduced deflection and turn on the red LED. When placed on a moist substance the device switches and the green LED goes off while the red LED comes on. Table 1 shows a summary of the results. Note that the resistance is measured between the two fingers. The results show that the presence of moisture can greatly reduce the body resistance and hence increase the risk of such an individual to electric shock.

Table 1: Tabulated results of certain individual

Individual	Body resistance without moisture [Ω]	Body resistance with moisture [Ω]	Body temp measured by the device [^{0}C]	Body temp measured by thermometer [^{0}C]
A	210K	1K	36.1	36.4
B	189K	1.2K	36.3	36.2
C	56K	5.5K	37	37.6
D	70K	4K	37.5	37.1
E	80K	6K	37.4	36.9

Table 2 shows the summary of the effect of current on the human body [10]. It can be seen from the table that women are more at risk of electric shock when exposed to the same amount of current as men. This table clearly shows the need to put on the necessary insulation to prevent electric shock.

Table 2: The effect of current on human beings

BODILY EFFECT	DIRECT CURRENT (DC)	60 Hz AC	10 Hz AC
Slight sensation felt at hand	Men = 1.0 mA	0.4 mA	7 mA
	Woman = 0.6 mA	0.3 mA	5 mA
Threshold of perception	Men = 5.2 mA	1.1 mA	12 mA
	Woman = 3.5 mA	0.7 mA	8 mA
Painful, but voluntary muscle control maintained	Men = 62 mA	9 mA	55 mA
	Woman = 41 mA	6 mA	37 mA
Painful, unable to let go of wires	Men = 76 mA	16 mA	75 mA
	Woman = 51 mA	10.5 mA	50 mA
Severe pain, difficulty breathing	Men = 90 mA	23 mA	94 mA
	Woman = 60 mA	15 mA	63 mA
Possible heart fibrillation after 3 seconds	Men = 500 mA	100 mA	
	Men = 500 mA	100 mA	

Conclusion

The aim of this work was to design and construct a body resistance and temperature measurement device. The required circuit has been designed, constructed and found to be working satisfactorily. The device is able to measure the human body resistance and temperature by means of a sensing probe. The results obtained compares well with the human body resistance results obtained from other research work which is about 10K to 100k between dry fingers and as low as 300Ω between wet fingers [11,12]. The output is read out across meters and LEDs. The device finds application in homes and industries as a safety, moisture detector and a temperature measurement device. The device can also be modified to act as a lie-detector.

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